Total Maximum Daily Load of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland

I. Introduction

The Environmental Protection Agency Region III (EPA) establishes these Total Maximum Daily Loads (TMDLs) for nutrients and other oxygen demanding pollutants in order to attain and maintain the applicable Water Quality Standards (WQS) for dissolved oxygen (DO) in the Christina River Basin under low-flow conditions. EPA has established these TMDLs in cooperation with the Pennsylvania Department of Environmental Protection (DEP), Delaware Department of Natural Resources and Environmental Control (DNREC), Maryland Department of the Environment (MDE) and the Delaware River Basin Commission (DRBC). As part of these TMDLs, EPA has allocated specific amounts of nutrients and other oxygen demanding pollutants to certain point and nonpoint sources necessary to restore and maintain the applicable WQS. These TMDLs recommend that seven facilities, six in Pennsylvania and one in Maryland, have their National Pollution Discharge Elimination System (NPDES) permits modified when next reissued to reduce the amounts of pollutants that may be discharged.

A related, but separate, effort is underway to establish TMDLs for nutrients, DO and other pollutants causing water quality problems under high-flow conditions. EPA expects these high-flow TMDLs to be completed by December 2004.

II. Historical Perspective

In 1991, at the request of DNREC and DEP, DRBC agreed to mediate water management issues in the “interstate” Christina River Basin. The issues included interstate and intrastate coordination of monitoring, modeling, and pollution controls; balancing the conflicting demands for potable water while maintaining necessary minimum pass-by requirements to sustain aquatic life; protection of vulnerable, high quality scenic and recreational areas; restoration of wetlands and other critical habitats; and implementation of Delaware’s Exceptional Recreational or Ecological Significance (ERES) objectives. A comprehensive basin approach was needed.

The DRBC facilitated a series of meetings with DNREC, DEP, EPA, Chester County Water Resources Authority (CCWA) and the United States Geological Survey (USGS). EPA funded a study by Scientific Applications International Corporation (SAIC) for completion of an initial data assessment and problem identification study for the non-tidal portion of Brandywine Creek. The findings of this study, *Preliminary Study of the Brandywine Creek Sub-basin, Final Report, September 30, 1993*, provided a framework for use in a multi-step TMDL study for the entire Christina River Basin. The two states, DRBC and EPA reached agreement in late 1993 to initiate a cooperative and coordinated monitoring and modeling approach to produce Christina River Basin TMDLs for low-flow conditions by late 1999.

Even as the parties reached agreement on how best to address the impacts of pollutants during low-flow conditions, they recognized that additional efforts would be necessary to address the distinct water quality problems resulting from primarily nonpoint sources of pollutants during high-flow conditions. In 1993, EPA recommended that DRBC expand the effort to consider high-flow conditions. As a result, the Christina Basin Water Quality Management Committee (CBWQMC) was created with the purpose of addressing the applicable water quality problems and management policies on a watershed scale. The CBWQMC represents a variety of stakeholders and interested parties including the Brandywine Valley Association/Red Clay Valley Association (BVA/RCVA), Chester County Conservation District (CCCD), Chester County Health Department (CCHD), Chester County Planning Commission (CCPC), CCWA, DNREC, Delaware Nature Society (DNS), DRBC, New Castle County Conservation District (NCCD), DEP, EPA Region III, USGS, United States Natural Resources Conservation Service (USDA-NRCS) and the Water Resources Agency for New Castle County (WRANCC).

The CBWQMC developed a unified, multi-phased, 5-year Water Quality Management Strategy (WQMS) that firsts, addresses the water quality problems through voluntary watershed/water quality planning and management activities and second, establishes appropriate TMDLs. The reason for separating the development of TMDLs to address water quality problems between low-flow and high-flow TMDLs is that each scenario has different and distinct pollutants and problems at different flow regimes.

Since 1995, the CBWQMC has been conducting activities set forth in the WQMS designed to implement programs aimed at protecting and improving water quality. These activities include Geographic Information System (GIS) watershed inventory, water quality assessment, watershed pollutant potential and prioritization, stormwater monitoring, Best Management Practices (BMP) Implementation projects and public education/outreach. A summary of these activities can be found in *Phase I and II Report, Christina River Basin Water Quality Management Strategy, May 1998* and *Phase III Report, Christina Basin Water Quality Management Strategy, August 5, 1999.* These reports describe ongoing efforts to provide pollution control and restore water quality within the Christina River Basin.

Both Pennsylvania and Delaware have identified multiple segments and pollutants in the Christina River Basin on their respective lists of impaired waters still requiring the development of a TMDL. Based on available information, Pennsylvania identified 24 stream segments on its 1998 303(d) list while Delaware identified 15 stream segments on its 1998 303(d) list as not meeting WQS for nutrients and low DO within the Christina River Basin. The Clean Water Act (CWA) requires that upstream waters must meet the applicable WQS of the downstream state at or before the state line. In other words, any TMDL to achieve the WQS in the Christina River Basin in Delaware requires Pennsylvania waters to meet WQS at the Delaware state line.

Concurrent with the water quality improvement activities taking place within the Christina River Basin, EPA settled two civil lawsuits regarding EPA's oversight of the TMDL programs of Pennsylvania and Delaware. Both suits alleged violations of the CWA, the Endangered Species Act (ESA) and the Administrative Procedures Act (APA). The settlement of the Pennsylvania matter, American Littoral Society and the Public Interest Research Group v. EPA, Civil No. 96-489 (E.D. Pa), was entered on April 9, 1997. The Pennsylvania TMDL settlement requires certain numbers of TMDLs by certain dates but gives discretion to Pennsylvania and EPA as to which TMDLs must be completed. The settlement of the Delaware lawsuit, American Littoral Society and Sierra Club v. EPA Civil Action No. 96-591 (SLR) (D.De), was entered on August 9, 1997. The Delaware TMDL settlement sets forth specific deadlines for EPA relating to specific waters and TMDLs in the Christina Rivern Basin. Under the schedule set forth the settlement, Delaware was to establish low-flow TMDLs for all water quality limited segments (except for those impaired by bacteria), including Brandywine Creek, Christina River, Red Clay Creek and White Clay Creek, by December 31, 1999. The Delaware settlement also expects Delaware to establish high-flow TMDLs by December 31, 2004. Pursuant to the Delaware agreement, EPA is required to establish TMDLs within one year should Delaware fail to do so.

In response to the requirement to establish TMDLs, Delaware, in cooperation with the CBWQMC, identified the need for a scientific modeling tool to investigate water quality impairments related to the development of TMDLs in the Christina River Basin. Tetra Tech, already under contract to EPA (Contract No. 68-C7-0018), was asked to provide regional TMDL watershed analysis and support within the Christina River Basin. The original work plan was approved August 28, 1997 with the purpose of providing a calibrated water quality model for nutrients and DO for the Christina River Basin to be used by DNREC and DEP in establishing TMDLs. The model would be calibrated for critical, low-flow summer period, use all available information and include both point and nonpoint sources. The WASP5[1] model was originally envisioned as the analytical tool, however, EPA ultimately decided to use the EFDC[2] model after considering the complexity of the Christina River Basin and the need to link this model with the HSPF[3] model being developed by the USGS to characterize high-flow conditions. The work plan was further expanded on April 20, 1999 to include additional reaches in Delaware and allow for further validation of the model.

Following DNREC's request for scientific modeling support, a model/technical group was

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[1] Ambrose, R.B., T.A. Wool, and J.L. Martin. 1993. The water quality analysis and simulation program, WASP5 version 5.10. Part A: Model documentation. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, GA.

[2] Hamrick, J.M. 1992. A three-dimensional environmental fluid dynamics computer code: theoretical and computational aspects. SRAMSOE #317, The College of William and Mary, Gloucester Point, VA.

[3] Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S. Donigan, and R.C. Johanson. 1993. Hydrological Simulation Program-FORTRAN (HSPF): User's manual for release 10.0. EPA 600/3-84-066. Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA.

formed to develop the scientific modeling tool within the Christina River Basin. Members who participated in this effort include representatives from DNREC, DEP, EPA, DRBC, USGS and Tetra Tech. Although the Cecil County, Maryland Department of Public Works and MDE were not originally included, once it was discovered that these TMDLs would impact point sources in Maryland, these organizations were contacted and have participated in the development of the TMDLs since May 2000.

After Tetra Tech began providing TMDL watershed analysis and support in 1998, the model/technical group met on a consistent basis in order to develop the modeling tool in support of the requirement to establish TMDLs for low-flow conditions by December 31, 1999. In September 1998, when it became apparent that the model development was behind schedule, and at the request of Delaware and Pennsylvania, the DRBC agreed, by resolution, to hire Widener University to further assist in the development of TMDLs once the model was completed. Despite best efforts by DRBC, EPA, the states and other participants on the CBWQMC, the low- flow TMDLs for the Christina were not completed by December 1999. EPA thereafter assumed the lead to establish these TMDLs.

III. Christina River Basin Water Quality Perspectives

In addition to the legal, statutory and regulatory requirements of identifying water quality limited segments and establishing TMDLs, there are several compelling reasons why establishing these TMDLs is good public policy to address the water quality of the Christina River Basin: (1) protect water quality uses, (2) protect sources of drinking water, and (3) promote appropriate growth. One goal of the CWA, and other similar legislation, is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. These critical, but often delicate natural resources, can be easily degraded by anthropogenic and other sources of pollution. Polluted waters can affect the quality of life, health and vitality of citizens in the Christina River Basin. Consistent with the goals of the CWA, it is in the public interest to sustain the diverse human, ecological, aesthetic and recreational resources of the watershed.

While it is often times extremely difficult to attach a precise economic value to natural resources such as the Nation's waters, the CWA recognizes the benefits gained by restoring and maintaining the Nation's waters. Actions such as these become even more critical where the waterbody serves as the primary source of drinking water for 75% of the residents in New Castle County, Delaware. Many of the water supply withdrawals in Chester County, Pennsylvania originate in waters from the Christina River Basin. Development will continue to occur in the Christina River Basin along with the consequential impacts on water quality. Establishing protective and appropriate water quality targets will allow progress while ensuring water quality integrity.

EPA characterizes the past and current condition of water quality in the Christina River Basin, as well as assesses available data, as part of the basis for these TMDLs. Data appendices prepared for this report describes in detail the existing water quality during low flow. The data assessment discussion developed by Dr. John Davis of Widener University, in draft form for the DRBC TMDL determination, has been included verbatim from the "*Preliminary Draft TMDL Document 5/27/99*" provided to DRBC on June 7, 1999. EPA used this data in developing these TMDLs. These appendices can be conveniently viewed at the EPA Region III Christina River Basin TMDL web site (www.epa.gov/reg3wapd/christina).

IV. Basin Summary and Source Assessment

The Christina River Basin (Hydrologic Unit Code 02040205) covers an area of 564.06 square miles and is located in Chester County, Pennsylvania, New Castle County, Delaware and Cecil County, Maryland (Figure 1). Major streams in the Christina River Basin include the Christina River (tidal and nontidal), Brandywine Creek (tidal and nontidal), Red Clay Creek and White Clay Creek (tidal and nontidal). The Christina River Basin drains to the tidal Delaware River at Wilmington, Delaware. The streams in the Christina River Basin are used as habitat for aquatic life, for municipal and industrial water supplies and for recreational purposes. The portions included in the model appear as thick or outlined segments of the streams in Figure 1.

The Christina River Basin is composed of diverse land uses including urban, rural and agricultural areas. The land use distribution within the basin is summarized in Table 1 below.

Table 1. Land Use Summary (acres)

Land Use	Delaware/ Maryland	Pennsylvania	Total	%
Urban/Suburban	87	108	195	34
Agricultural	18	160	178	31
Open Space or Protected Lands	21	5	26	5
Wooded	37	123	160	28
Water/other	3	3	6	2
Total	166	399	565	100

Source: Phase I/II Report Christina River Basin Water Quality Management Strategy (CBWQMC - May 1998)

The major urban areas in the watershed include greater Wilmington and Newark, Delaware, and the Pennsylvania towns of West Chester, Downingtown, Kennett Square, Coatesville, Parkesburg, Honey Brook, Avondale and West Grove.

There are 122 NPDES dischargers included in the Christina River Basin TMDL analysis (see

Table 2 and Figure 2). The discharges range from single resident discharges (about 500 gallons per day (gpd)) to large industrial and municipal wastewater treatment plants with effluent flow rates in the range of 1 to 7 million gallons per day (mgd). The largest NPDES facilities in the Christina River Basin are Downingtown (permitted flow of 7.00 mgd), Sonoco (3.00 mgd), West Chester Taylor Run (1.50 mgd), Lukens Steel (1.00 mgd), Coatesville (3.85 mgd), South Coatesville (0.39 mgd), Kennett Square (1.10 mgd) and Avondale (0.30 mgd). There are seven NPDES facilities with flows above 10 mgd that discharge to the tidal Delaware River portion of the model, the largest being the City of Wilmington (now rated at 134 mgd).

V. Problem Identification and Understanding

In response to the requirements of Section 303(d) of the CWA, DEP and DNREC listed multiple Christina River Basin waterbodies on their 1996 and 1998 303(d) lists of impaired waterbodies based on available information. As noted earlier, Pennsylvania identified 24 stream segments on its 1998 303(d) list (Table 3) while Delaware identified 15 stream segments on its 1998 303(d) list (Table 4) as not meeting WQS for nutrients and low DO within the Christina River Basin. Pursuant to the TMDL Consent Decree in Delaware, those 15 stream segments were given high priority. Likewise, Pennsylvania identified 23 of the 24 listed segments as high priority. A number of monitoring stations are located throughout the Christina River Basin within the listed waters (Figures 3 and 4). Data from these stations were used to determine the impairment and inclusion on the 303(d) lists based on the number of values exceeding WQS for DO. Excessive nutrients, organic enrichment and low DO are specified as the causes of impairment in the various listed stream segments. The pollutant sources are varied and include industrial and municipal point sources, agriculture, Superfund sites and hydromodification. An extensive data assessment is provided in the appendices at the web site (www.epa.gov/reg3wapd/christina).

These TMDLs also address loadings of pollutants from waterbodies or segments which have not been listed as impaired on the states' 303(d) lists. The CWA requires for interstate waters that the water from the upstream state meet the WQS of the down stream state at or before the state line. In this case, these interstate TMDLs not only address the segments listed respectively by Pennsylvania (the upstream state) and Delaware (the downstream state), but also address other water quality problems associated with discharges from non-listed waters necessary to protect the water quality of downstream waters of Delaware during low-flow conditions. In a few cases, including certain segments of the East Branch of the Brandywine River, the TMDL modeling also revealed problems in previously unlisted waters where none had been identified before. In some cases where a segment may not have been previously identified as impaired, these TMDLs allocate pollutant loads that are causing or contributing to the impairment of that water and/or downstream waters. EPA established such wasteload allocations in order to attain and maintain the applicable WQS of both upstream and downstream waters consistent with our authority to establish these TMDLs.

Table 3. Christina River Basin Stream Reaches on the PA 1998 303(d) List

Watershed	Stream ID	Segment ID	Miles	Source of Impairment	Cause of Impairment
Brandywine Creek	00004	27	1.28	other	nutrients
Buck Run	00131	50	1.77	municipal point source	nutrients, low DO
Sucker Run	00202	970930-1437-GLW	6.78	agriculture	nutrients
W.Br. Brandywine Creek	00085	970618-1118-GLW 970618-1340-GLW 970619-1222-GLW 970619-1345-GLW	2.98 3.57 5.51 3.99	agriculture	nutrients
Broad Run	00434	971209-1445-ACW	4.10	hydromodification, agriculture	organic enrichment, low DO, nutrients
E.Br. Red Clay Creek	00413	971023-1050-MRB 971204-1400-ACW	6.53 5.09	agriculture	organic enrichment, low DO
E.Br. White Clay Creek	00432	970409-1130-MRB 970506-1320-MRB 970508-1430-ACE 971113-1335-GLW 971119-1116-GLW 971120-1331-GLW	6.07 8.61 2.44 3.10 1.21 8.12	agriculture	nutrients nutrients organic enrichment, low DO organic enrichment, low DO nutrients nutrients
Egypt Run	00440	970508-1245-ACE	3.66	agriculture	organic enrichment, low DO
Indian Run	00475	115	1.09	agriculture, municipal point source	nutrients
Middle Br. White Clay	00462	115	17.33	agriculture, municipal point source	nutrients
Red Clay Creek	00374	971203-1400-ACW	0.76	agriculture	organic enrichment, low DO
Trout Run	00402	970506-1425-MRB	2.74	agriculture	nutrients
Walnut Run	00435	971209-1445-ACW	1.39	agriculture, hydromodification	organic enrichment, low DO, nutrients
W.Br. Red Clay Creek	00391	971023-1145-MRB	4.58	agriculture	organic enrichment, low DO
White Clay Creek	00373	971216-1230-GLW	1.13	agriculture	nutrients

Source: Excerpt PADEP Final 1998 Section 303(d) List, Submitted August 7, 1998 and Approved by EPA on August 27, 1998

Table 4. Christina River Basin Stream Reaches on the DE 1998 303(d) List

Waterbody ID	Watershed Name	Segment	Miles	Pollutants/Stressor	Probable Sources
DE040-001	Brandywine Creek	Lower Brandywine	3.8	nutrients	PS, NPS, SF
DE040-002	Brandywine Creek	Upper Brandywine	9.3	nutrients	PS, NPS, SF
DE260-001	Red Clay Creek	Main Stem	12.8	nutrients	PS, NPS, SF
DE260-002	Red Clay Creek	Burroughs Run	4.5	nutrients	NPS
DE320-001	White Clay Creek	Main Stem	18.2	nutrients	PS, NPS
DE320-002	White Clay Creek	Mill Creek	16.6	nutrients	NPS
DE320-003	White Clay Creek	Pike Creek	9.4	nutrients	NPS
DE320-004	White Clay Creek	Muddy Run	5.8	nutrients	NPS
DE120-001	Christina River	Lower Christina	1.5	nutrients, DO	NPS, SF
DE120-002	Christina River	Middle Christina River	7.5	nutrients	NPS, SF
DE120-003	Christina River	Upper Christina River	6.3	nutrients	NPS, SF
DE120-003-02	Christina River	Lower Christina Creek	8.4	nutrients	NPS
DE120-005-01	Christina River	West Branch	5.3	nutrients	NPS
DE120-006	Christina River	Upper Christina Creek	8.3	nutrients	NPS
DE120-007-01	Christina River	Little Mill Creek	12.8	nutrients, DO	NPS, SF

PS= point source; NPS = nonpoint source; SF=superfund site

Source: Excerpt DNREC Final 1998 Section 303(d) List, Submitted July 7, 1998 and Approved by EPA on July 17, 1998

EPA developed these TMDLs using the underlying principles of the Watershed Protection Approach. EPA's Watershed Protection Approach is governed by the principle that many water quality and ecosystem problems are best solved at the larger watershed levels rather than on the smaller, individual waterbody or discharger level. The Watershed Protection Approach increases the ability to identify and target priority problems, promotes broader stakeholder involvement, integrates solutions which use all available expertise and provides a better measure of success through the use of data and monitoring. Managing water resources on a watershed basis makes sense environmentally, financially and socially.

As indicated in the data assessment found in the appendices at the Christina TMDL web site, the nutrient concentrations of the tidal Christina River are heavily influenced by tributary loads from the Brandywine Creek, Red and White Clay Creeks and nontidal Christina River. The data analysis also indicates that DO concentrations within the tidal Christina River violate both the minimum and daily average WQS during critical conditions. In addition to the influential nutrients loads from tributaries, spatial data analysis indicates that high levels of phytoplankton biomass are likely the result of transport from inland tributaries. In any case, the nutrient and biomass loadings from inland tributaries contribute to the DO WQS violations within the tidal Christina River. This further justifies the need to consider sources of pollutants and tributaries on a watershed basis, regardless of whether that waterbody is explicitly listed on a state's 303(d) list.

Excess nutrients in a waterbody can have many detrimental effects on designated or existing uses, including drinking water supply, recreational use, aquatic life use and fishery use[4]. Eutrophication, a term usually associated with the natural aging process experienced by lakes, describes the excessive nutrient enrichment of streams and rivers which can experience an undesirable abundance of plant growth, particularly phytoplankton (photosynthetic microscopic organisms (algae)), periphyton (attached benthic algae) and macrophytes (large vascular rooted plants). Photosynthesis and respiration of these plants as well as the microbial breakdown of dead plant matter contribute to wide fluctuations in the DO levels in streams. The impact of low DO concentrations or of anaerobic conditions is reflected in an unbalanced ecosystem, fish mortality, odors and other aesthetic nuisances[5]. These types of impairments interfere with the designated uses of waterbodies by disrupting the aesthetics of the river, causing harm to inhabited aquatic communities and causing violations of applicable water quality criteria.
Figure 5 below shows the interrelationship of the major processes which affect DO.

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[4] U.S. Environmental Protection Agency. 1999. Protocol for Developing Nutrient TMDLs. Pg 2-1. EPA 841-B-99-007. Office of Water (4503F). U.S. EPA, Washington D.C. 135pp.

[5] Thomann, R.V., J.A. Mueller. 1987. Principles of Surface Water Quality Modeling. HarperCollins Publishers, Inc. Section 6.1.

The presence of aquatic plants in a waterbody can have a profound effect on the DO resources and the variability of the DO throughout a day or from day to day[6]. Growing plants provide a net addition of DO to the stream on an average daily basis through photosynthesis, yet respiration can cause low DO levels at night that can affect the survival of less tolerant fish and aquatic life species. This is due to the photosynthetic and respiration processes of aquatic plants which can cause large diurnal variations in DO that are harmful to fish and aquatic life. Photosynthesis is the process by which plants utilize solar energy to convert simple inorganic nutrients into more complex organic molecules[7]. Due to the need for solar energy, photosynthesis only occurs during daylight hours and is represented by the following simplified equation (proceeds from left to right):

$$\underset{\text{(Carbon Dioxide)}}{6CO_2} \quad + \quad \underset{\text{(Water)}}{6H_20} \quad \text{<----------->} \quad \underset{\text{(Sugar)}}{C_6H_{12}O_6} \quad + \quad \underset{\text{(Oxygen)}}{6O_2}$$

In this reaction, photosynthesis is the conversion of carbon dioxide and water into sugar and oxygen such that there is a net gain of DO in the waterbody. Conversely, respiration and decomposition operate the process in reverse and convert sugar and oxygen into carbon dioxide and water resulting in a net loss of DO in the waterbody. Respiration and decomposition occur at all times and are not dependent on solar energy. Also, if environmental conditions cause a die-off of either microscopic or macroscopic plants, the decay of biomass can cause severe oxygen depressions. Waterbodies exhibiting typical diurnal variations of DO experience the daily maximum in mid-afternoon during which photosynthesis is the dominant mechanism and the daily minimum in the predawn hours during which respiration and decomposition have the greatest effect on DO and photosynthesis is not occurring. Therefore, excessive plant growth, as a result of excessive nutrients, can affect a streams ability to meet both average daily and instantaneous DO standards[8].

Sediment oxygen demand (SOD) is due to the oxidation of organic matter in bottom sediments[9]. The organic matter originates from various sources including wastewater treatment facilities, leaf litter, organic-rich soil or photosynthetically produced plant matter which settles and accumulates. In some instances, SOD can be significant portion of total oxygen demand, particularly in small streams where the effects may be more pronounced during low-flow or high temperature conditions[10].

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[6] Supra, footnote 5. (Thomann, Mueller) Section 6.3.3.

[7] Chapra, S.C. 1997. Surface Water-Quality Modeling. WCB/McGraw-Hill. Section 19.1.

[8] U.S. Environmental Protection Agency. 1997. Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication. Office of Water(4305). EPA 823-B-97-002. Section 4.2.1.2.

[9] Supra, footnote 7. (Chapra) Section 25

[10] Supra, footnote 8. (EPA Guidance Manual for Developing TMDLs) Section 2.3.4.4.

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen required to stabilize organic matter in wastewater[11]. It is typically determined from a standardized test measuring the amount of oxygen available after incubation of the sample at 20°C for a specific length of time, usually five days. Conceptually, BOD requires a distinction between the oxygen demand of the carbonaceous material in waste effluents and the nitrogenous oxygen demanding component of an effluent[12]. Carbonaceous biochemical oxygen demand (CBOD) involves the breakdown of organic carbon compounds while nitrogenous biochemical oxygen demand (NBOD) involves the oxidation of ammonia to nitrate, referred to as the nitrification process[13].

VI. Christina River Basin Water Quality Model

Thomann and Mueller[14] define a model as "a theoretical construct, together with assignment of numerical values to model parameters, incorporating some prior observations drawn from field and laboratory data, and relating external inputs or forcing functions to system variable responses." In order to evaluate the linkage between the applicable water quality criteria numbers (endpoints) and the identified sources and establish the cause-and-effect relationships, EPA is utilizing the EFDC water quality model. EFDC is a public domain surface water modeling system incorporating fully integrated hydrodynamic, water quality and sediment-contaminant simulation capabilities.

EFDC is extremely versatile and can be applied in 1,2, or 3 dimensional simulation of rivers, lakes and estuaries with coupled salinity and temperature transport. Further capabilities of the model include a directly coupled water quality-eutrophication and toxic contaminated sediment transport and fate models, integrated near-field mixing zone model, as well as pre- and post-processing for input file creation, analysis and visualization. The eutrophication component of EFDC can simulate the transport and transformation of 22 state variables including cyanobacteria, diatom algae, green algae, refractory particulate organic carbon, labile particulate organic carbon, dissolved carbon, refractory particulate organic phosphorus, labile particulate organic phosphorus, dissolved organic phosphorus, total phosphate, refractory particulate organic nitrogen, labile particulate organic nitrogen, dissolved organic nitrogen, ammonia nitrogen, nitrate nitrogen, particulate biogenic silica, dissolved available silica, chemical oxygen demand, dissolved oxygen, total active metal, fecal coliform bacteria and macroalgae. The EFDC model has been used in similar water quality studies including the Peconic Estuary, the Indian River Lagoon/Turkey Creek and the Chesapeake Bay system and the EFDC model was used to develop TMDLs for waterbodies in Oklahoma and Georgia, including Wister Lake, OK (2000), and the St. Mary's and Suwanee Watersheds, GA (2000).

[11] Supra, footnote 8. (EPA Guidance Manual for Developing TMDLs) Section 2.3.4.

[12] Supra, footnote 5. (Thomann, Mueller) Section 6.3.1.

[13] Supra, footnote 7. (Chapra) Section 19.4.

[14] Supra, footnote 5. (Thomann, Mueller) Section 1.2.1.

In order to ensure that the EFDC model is adequately representing the hydrodynamic and water quality processes of the Christina River Basin, separate calibration and validation of the model was performed to establish model robustness[15]. Calibration involves adjusting kinetic parameters within the model to achieve a specified level of performance in comparison to actual observed hydrodynamic and water quality data from a basin. The model calibration was executed over a period of 143 days from May 1 to September 21, 1997. EPA also validated the Christina River Basin model to confirm and provide additional confidence that the model can be used as an effective prediction tool for a range of conditions other than those in the original calibration. During validation, the kinetic parameters which were adjusted during calibration remain fixed to evaluate the model accuracy in representing the Christina River Basin. The model validation was executed over a period of 143 days from May1 to September 21, 1995. Point source loads during calibration and validation are representative of actual discharged loads as listed on Discharge Monitoring Reports (DMRs) during the calibration or validation periods. Nonpoint source loads are based on STORET data, USGS water quality data, baseflow sampling, and data from interstate monitoring efforts during the calibration or validation periods. These loads represent contributions from nonpoint sources and form the basis of the load allocations.

EPA also provides an assessment of the calibration and validation quality. There are two general approaches for assessing the quality of a calibration: subjective and objective[16]. The subjective assessment typically involves visual comparison of the simulation with the data, as in time series plots for state variables, while the objective assessment utilizes quantitative measures of quality such as statistical measures of error. EPA included both types of assessment and compared the Christina River Basin model error statistics with those from other similar studies. The Christina River Basin model compares very favorably as discussed in Section 11 of the *Hydrodynamic and Water Quality Model of Christina River Basin Final Report, May 31, 2000.* A complete and more-detailed technical discussion of the EFDC model is available in this report.

The calibrated and validated water quality model was used to confirm that the model was able to simulate the locations of the impaired stream segments on the 303(d) lists. The model results from the 1997 calibration run were plotted on a map view of the Christina River Basin and those model grid cells not meeting the daily average and minimum DO water quality criteria were highlighted (see Figures 6 and 7). The 1997 calibration results indicate that the daily average DO criteria were not met in portions of the tidal Christina River, tidal Brandywine Creek, tidal White Clay Creek, West Branch Red Clay Creek and Little Mill Creek (Figure 6). The 1997 calibration results also indicate that the minimum DO criteria were not protected in portions of the West Branch Red Clay Creek, Little Mill Creek and tidal Brandywine Creek (Figure 7).

A separate analysis was performed to investigate potential WQS violations during critical

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[15] Supra, footnote 7. (Chapra) Section 18.1.5.

[16] Supra, footnote 7. (Chapra) Section 18.3.

conditions. During this scenario, the NPDES point source discharges were set to their maximum permitted flows and concentrations and the model was run under 7Q10 (minimum 7-day flow expected to occur every 10 years) stream flow conditions. Nonpoint source pollutant loads, as computed by multiple data sets, were developed to represent expected conditions and pollutant contributions during critical periods. The use of actual site-specific data to characterize nonpoint sources is appropriate and would essentially act to integrate past pollutant loading events. While the process of calibrating and validating the water quality model was dynamic, the critical condition analysis is representative of steady-state conditions. Tidal elevations at the north and south boundaries on the Delaware River were set using tidal harmonic constants derived from NOAA subordinate tide stations at Chester, Pennsylvania, and Reedy Point, Delaware. Map-view graphics were created to highlight problem areas (see Figures 8 and 9).

The model results from the period of August 1 through August 31, when critical stream flows are most likely to occur, indicate that the daily average DO criteria will not be satisfied in portions of the West Branch Brandywine Creek, East Branch Brandywine Creek below Downingtown, Brandywine Creek main stem, West Branch Red Clay Creek, West Branch Christina River and tidal Christina River (Figure 8). The model results also indicate that the minimum DO criteria will not be achieved in portions of the West Branch Brandywine Creek, East Branch Brandywine Creek below Downingtown, Brandywine Creek main stem and West Branch Red Clay Creek (Figure 9).

The tidal estuary portion of the EFDC model is used to characterize the Delaware River Estuary and consider potential impacts to water quality within the Christina River Basin from pollutant loads to the estuary. Of the 122 NPDES dischargers evaluated in this TMDL assessment, 23 are point sources discharging to the Delaware River which were considered in the linkage analysis. In considering which dischargers to include, the spatial range was limited to about 10 miles above and below the confluence of the Christina River and the Delaware River due to the tidal excursion, which is approximately eight miles.

While this TMDL analysis and subsequent allocation scenarios are designed to address low-flow conditions and the contributions from the primary sources (point sources), the analysis includes land-based nonpoint sources. As discussed further below, because at low-flow conditions there are no significant nonpoint source contributions, the nonpoint source allocation is included as part of the background loading. Addressing this critical condition establishes the baseline condition which point sources within the Christina River Basin must comply with in order to achieve WQS.

The stream reaches identified by the model as not meeting DO criteria are in general agreement with those on the 303(d) lists. EPA believes that the Christina River Basin model is an appropriate tool for understanding the current water quality problems in the Christina River Basin, evaluating the linkage between cause-and-effect and allocating pollutant loads to identified sources.

VII. Discussion of Regulatory Conditions

Federal regulations at 40 CFR Section 130 require that TMDLs must meet the following eight regulatory conditions:

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3) The TMDLs consider the impacts of background pollutant contributions.
4) The TMDLs consider critical environmental conditions.
5) The TMDLs consider seasonal environmental variations.
6) The TMDLs include a margin of safety.
7) The TMDLs have been subject to public participation.
8) There is reasonable assurance that the TMDLs can be met.

EPA provides the following information to demonstrate how the Christina River Basin TMDLs meet these eight regulatory requirements.

1) The TMDLs are designed to implement applicable water quality standards.

Target Analysis

The CWA requires states to adopt WQS to define the water goals for a waterbody by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses and by protecting water quality through antidegradation provisions. These standards serve dual purposes: they establish water quality goals for a specific waterbody, and they serve as the regulatory basis for establishing water quality-based controls and strategies beyond the technology-based levels of treatment required by sections 301(b) and 306 of the CWA[17].

Within the Christina River Basin, there are four regulatory agencies which have applicable WQS. The DEP, DNREC, and MDE have WQS which apply to those stream segments of the

[17] U.S. Environmental Protection Agency. 1994. Water Quality Standards Handbook: Second Edition. Office of Water(4305). EPA 823-B-94-005a. Section 2.1.

Christina River Basin located in the respective state. The DRBC[18] is an interstate agency which has the authority to establish WQS and regulate pollution activities within the Delaware River Basin including the Christina River Basin, one of the Delaware River's tributary basins. Tables 5 and 6 below summarizes the applicable WQS relating to DO and nutrients.

Table 5. Summary of Applicable Use Designations and DO Criteria

Agency	Designated Use	D.O. Criteria (mg/L)		Comments
		Daily avg.	Minimum	
PADEP	Warm water fish (WWF)	5.0	4.0	
	Cold water fish (CWF)	6.0	5.0	
	Trout stocking fishery (TSF)	6.0 5.0	5.0 4.0	Feb 15 - Jul 31 Aug 01 - Feb 14
	High Quality CWF		7.0	Special Protection Waters
	High Quality TSF	6.0	5.0	Special Protection Waters
	Exceptional value			Special Protection Waters
DNREC	Fresh waters	5.5*	4.0	*Average for June-September period shall not be less than 5.5 mg/L
	Cold water fish	6.5	5.0	Seasonal
	Marine waters	5.0	4.0	Salinity greater than 5.0 ppt
	Exceptional recreation or ecological significance			Existing or natural water quality
MDE	Fresh waters	5.0	5.0	Use I waters, DO must not be less than 5.0 mg/L at any time
DRBC	Resident game fish	5.0	4.0	
	Trout	6.0	5.0 7.0	 During spawning season
	Tidal: resident or anadromous fish	4.5		6.5 mg/L seasonal average during Apr 01 - Jun 15 and Sep 16 - Dec 31

Table 6. Summary of Nutrient Criteria

[18] The DRBC was created by compact among Pennsylvania, New Jersey, New York, Delaware and the federal government in 1961.

Parameter Agency	Comments
Ammonia-Nitrogen	
PADEP	1-day and 30-day average ambient criteria are a function of pH and temperature for toxicity; Implementation Guidance document for Ammonia allocations for NBOD and Toxicity.
DNREC	No specific numeric criteria; Narrative statement for prevention of toxicity.
DRBC	NPDES effluents limited to a 30-day average of 20 mg/L as N.
Nitrate-Nitrogen	
PA DEP	Ambient criteria is maximum of 10 mg/L as N applied at the point of water supply intake, not at the point of an effluent discharge. For the case of an interstate stream, the state line shall be considered a point of water supply intake.
DNREC	Ambient nitrate criteria is maximum of 10 mg/L as N; provision for site-specific nutrient controls. The DNREC 303(d) rationale document cites 3.0 mg/L total nitrogen as guidance for determining impairment.
DRBC	No specific numeric criteria.
Phosphorus	
PA DEP	No specific numeric criteria are specified in the Pennsylvania Code, Title 25, Chapter 93 (Water Quality Standards). According to Chapter 95 (Wastewater Treatment Requirements), phosphorus effluent limits are set to a maximum of 2 mg/L whenever the Department determines that instream phosphorus alone or in combination with other pollutants contributes to impairment of designated stream uses.
DNREC	No specific numeric criteria; provision for site specific controls. The 303(d) rationale document cites 0.1 mg/L total phosphorus as guidance for use impairment.
DRBC	No specific numerical criteria.

Once EPA identifies the applicable use designation and water quality criteria, EPA determines the numeric water quality target or goal for the TMDL. These targets represent a number where the applicable water quality is achieved and maintained. In these TMDLs, the target is to attain and maintain the applicable DO water quality criteria at low-flow conditions. Figure 10 below shows the applicable use designations for stream segments included in the Christina River Basin TMDL. Using Tables 5 and 6 and Figure 10, the numeric water quality targets for DO can be identified for each segment. Table 7 below identifies the general water quality targets or endpoints for the Christina River Basin TMDLs.

Table 7. Summary of TMDL Endpoints

Parameter	Target Limit	Reference
Daily Average DO, freshwater, Pennsylvania	5.0 mg/L	Pennsylvania Water Quality Standards
Daily Average DO, freshwater, Delaware	5.5 mg/L	Delaware Water Quality Standards
Daily Average DO, tidal waters, Delaware	5.5 mg/L	Delaware Water Quality Standards
DO at any time, freshwater, Maryland	5.0 mg/L	Maryland Water Quality Standards
Minimum DO	4.0 mg/L	Pennsylvania and Delaware Water Quality Standards

In addition to the TMDL DO endpoints summarized in Table 7, there are higher DO WQS for certain Christina River Basin segments during the critical conditions time periods considered in these low-flow TMDLs. Generally, these segments were either not listed on 303(d) lists for point source impacts or found not to be impacted by point source discharges in the TMDL evaluations. The results of the TMDL model runs, incorporating the proposed TMDL reductions, indicate that these higher DO WQS will be protected. This information is summarized in a series of data plots showing DO levels and WQS for the major segments in the Christina River Basin found in Appendix A of this document.

These TMDLs have also identified the pollutants and sources of pollutants that cause or contribute to the impairment of the DO criteria and allocate appropriate loadings to the various sources. Given our scientific knowledge regarding the interrelationship of nutrients, BOD, SOD and their impact on DO, EPA determined it necessary and appropriate to establish numeric targets for total nitrogen and total phosphorus based on applicable state narrative criteria to support the attainment of the numeric DO criterion. Likewise, to maintain adequate instream levels of DO at low-flow conditions, EPA found it necessary and appropriate to develop as part of these TMDLs waste load allocations (WLAs) for total phosphorus, total nitrogen, ammonia-nitrogen, CBOD, and DO for point sources. Establishing numeric water quality endpoints or goals also provides the ability to measure the progress toward attainment of the WQS and to identify the amount or degree of deviation from the allowable pollutant load.

One Christina River Basin segment, the East Branch White Clay Creek, has been designated as Exceptional Value waters by Pennsylvania. In addition to TMDL results showing the DO WQS for this segment will be protected, the East Branch White Clay Creek is afforded additional protection of water quality conditions through the regulatory provisions of the Pennsylvania antidegradation program (25 PA Code Chapter 93.4 (c)) and 40 CFR 131.32.

While the ultimate endpoint for this TMDL analysis is to ensure that the WQS for DO are maintained throughout the Christina River Basin, it is necessary to determine if other applicable water quality criteria are met and maintained. Specifically, this applies to the Pennsylvania WQS for nitrate-nitrogen of 10 mg/l and ammonia-nitrogen which is based on temperature and pH. As a result of the pollutant load reductions necessary to maintain the water quality criteria for DO, the WQS for nitrate-nitrogen and ammonia-nitrogen of Pennsylvania were also evaluated. The ammonia-nitrogen standard is met throughout the Pennsylvania portion of the Christina River Basin. The only instances where the 10 mg/l nitrate nitrogen value is exceeded are small distances on the East Branch Brandywine Creek and West Branch Brandywine Creek. As there are no drinking water withdrawals at these locations, the standard is not applicable and additional reduction is not necessary.

Delaware WQS also set a numeric water quality criteria of 10 mg/l for nitrate-nitrogen. The WQS for nitrate-nitrogen of Delaware are met throughout the Delaware portion of the Christina River Basin. Delaware does not have numeric water quality criteria for ammonia-nitrogen, however, the analysis indicates that ammonia-nitrogen levels throughout the Delaware portion of the Christina River Basin are consistent with the recommended EPA water quality criterion from Section 304(a) of the CWA. Maryland does not have numeric water quality standards for ammonia-nitrogen and nitrate-nitrogen.

Achieving these in-stream numeric water quality targets will ensure that the designated uses (aquatic life and human health uses) of waters in Pennsylvania, Delaware, and Maryland are supported during critical conditions.

2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.

Total Allowable Load

The total allowable load for each portion of the Christina River Basin, as determined by the EFDC model, was calculated based on the segmentation of the model in order to better correspond with the 303(d) listing, ensure the integrity of each stream segment and to allow pollution trading alternatives. Table 8 below identifies the total allowable load as well as the WLAs, load allocations and margin of safety (MOS) for each of the 16 stream segments of the model.

Deposition from atmospheric sources is also considered in the Christina River Basin water quality model. While atmospheric deposition may not be as important in the narrow stream channels, it could become more important in the open estuary waterbodies in the lower Christina and Delaware rivers. Atmospheric loads are typically divided into wet and dry deposition. Wet deposition is associated with dissolved substances in rainfall. The settling of particulates during non-rainfall events contributes to dry deposition. Observations of concentrations in rainwater are frequently available and dry deposition is usually estimated as a fraction of the wet deposition. The atmospheric deposition rates reported in the Long Island Sound Study (HydroQual 1991) and the Chesapeake Bay Model Study (Cerco and Cole 1994) as well as information provided by DNREC for Lewes, Delaware, were used to develop both dry and wet deposition loads for the EFDC model of the Christina River Basin. Atmospheric deposition loads are included in Tables 12-28 as well as in the summary watershed calculations provided in Table 8.

Size-Based Equal Marginal Percent Removal Allocation Strategy

The general theory of WLAs, and more specifically the size-based equal marginal percent removal (EMPR) allocation strategy that is used for these TMDLs, is discussed in this section. While a complete and detailed understanding of the concepts discussed below is not essential to using the Christina River Basin water quality model, a general appreciation of underlying principles will aid the user in applying the model and interpreting the results. The strategy presented in this section is based largely upon the document *Implementation Guidance for the Water Quality Analysis Model 6.3* (Pennsylvania DEP 1986). While EPA has many ways of allocating pollutant loads, based on this discussion EPA determined the EMPR strategy to be sound, fair and consistent with the goals of the CWA.

The term “waste load allocation” refers to a specific set of circumstances in which two or more point source discharges are in sufficiently close proximity to one another to influence the level of treatment each must provide to comply with WQS. This definition is technically correct since without discharge interaction there is no need to share (i.e., to allocate) the assimilation capacity of the receiving water body. In a single discharge situation, all that needs to be done is to determine the level of treatment that must be provided to comply with WQS. The size-based EMPR analysis does this as a first step: (1) to determine if a WLA situation exists; and if it does, (2) to assign WLAs to each of the discharges that is contributing to the water quality violation. A WLA should have three major objectives: (1) to assure compliance with the applicable WQS; (2) to minimize, within institutional and legal constraints, the overall cost of compliance; and (3) to provide maximum equity (or fairness) among competing discharges.

The first objective, is fundamental to water quality and public health protection. It is an ethical statement that assumes the social, economic and environmental benefits of water pollution control outweigh the associated costs. This is consistent with the goals and requirements of the CWA.

The second objective is a statement of the desirability of economic efficiency. Resources devoted to one purpose are not available for another use. This holds true whether the resources are of a public or a private nature. It therefore behooves a water quality management program to achieve water quality management goals with maximum economic efficiency (i.e., at least cost). It can be shown that maximum efficiency is achieved when the marginal cost of pollution abatement is the same for all participants. The marginal cost of wastewater treatment is related to the marginal rate of removal. If it is assumed that the marginal cost per unit of removal is the same for all discharges, then maximum economic efficiency is achieved when the marginal rate of removal for all discharges is the same. Institutional and legal constraints may prevent water quality programs from achieving optimal economic efficiency. Nevertheless, maximum efficiency within existing institutional and legal constraints should be pursued.

The third objective is a social statement that goes hand in hand with the second objective. Maximizing economic efficiency would by definition, provide for maximum equity. The desirability of equity, especially in a regulatory program, among individual (and potentially competing) members of society is a reasonably well accepted concept. The specific definition of when (or how) equity is to be achieved is, however, open to debate and interpretation. The WLA strategy employed in this TMDL is that of EMPR. It is based on the premise that all dischargers, whether or not they are part of a WLA scenario, should provide sufficient treatment to comply with WQS, and that some dischargers, because they are part of an allocation scenario, must provide additional treatment, due to the cumulative impact that they and nearby dischargers have on the receiving stream.

The strategy is similar in most respects to more traditional uniform treatment approaches, where all dischargers provide the same degree of treatment. The major difference is in the selection of the baseline condition for the WLA process. In most traditional uniform treatment approaches all dischargers that are believed to be part of the WLA start at the same treatment level. The traditional approach introduces economic inefficiencies and inequities into the WLA process because it fails to consider the individual impact that each discharger has on the receiving stream. This individual impact is a function of the discharge size and location. The practical result of failing to take these factors into consideration is to impose unnecessarily stringent treatment requirements on smaller dischargers, solely because they happen to be in the vicinity of a larger discharger. This imposes higher than necessary costs on these smaller dischargers, and in effect, causes them to subsidize dischargers that have a greater impact on water quality. At the same time, uniform treatment does not significantly improve overall water quality.

In the size-based EMPR strategy, the baseline condition for each discharger is the level of treatment the discharge must provide if it is the only discharger to the receiving stream. This level of treatment is water quality based for this TMDL. It is a function of the discharge size and location. In selecting this baseline condition, there are no assumptions made as to whether a discharger is or is not part of an allocation scenario.

Once the baseline condition for each discharger is established, a determination is made of whether additional treatment is needed because of the cumulative impact of multiple discharges. The dischargers are added back into the model one at a time, based on the size of their load (i.e., kg/day of CBOD). The model is then run again. If additional treatment is necessary, then all dischargers contributing to the WQS violations are reduced by equal percentages, starting from their individual levels of treatment at the end of the previous model run. Thus, the marginal rate of removal for all affected dischargers is the same in any given model run, while the overall rate of removal for each may be different.

Another difference between the traditional uniform treatment approach and the size-based EMPR strategy is in the determination of which dischargers are part of the WLA scenario. In the uniform treatment approach, it is commonly assumed that the WLA segment starts at the first discharger that adversely affects in-stream conditions, and extends downstream to the point where the stream returns to background conditions. It is not entirely clear whether this assumption is absolutely required, or is merely a matter of convenience. In either case, the specification of a return to background stream quality tends to extend the allocation segment to include dischargers that may not be part of the allocation at all. This further increases the economic inefficiency and inequity of uniform treatment solutions.

The size-based EMPR WLA does not require any assumptions with regard to a return to background stream conditions. The strategy determines the downstream limit of the allocation problem based on compliance with WQS. These features, combined with the different baseline condition, makes size-based EMPR a more cost-efficient and equitable WLA strategy than the traditional methods.

Christina River Basin Allocation Process

The first consideration is to determine what time period to use for the allocation scenarios. Only the results from the model period August 1-31 were analyzed to determine the daily average DO and minimum DO for comparison to WQS and to direct the allocation scenarios. This time period was selected as most representative of when critical conditions are expected to occur within the system. The model was run for a sufficient period to allow for: (1) the nutrient loads to transport their way through system; (2) the predictive sediment diagenesis model to attain dynamic equilibrium; and (3) the algae to react to the availability of nutrients.

The size-based EMPR allocation process relies on three levels of analysis for the Christina River Basin. Level 1 involves analyzing each NPDES point source individually to determine the baseline levels of treatment necessary to achieve WQS for daily average and minimum DO. The point sources not being considered individually and the tributaries are set to the baseline conditions listed in Table 9 below. This allows the in-stream flow to remain at 7Q10 levels and provides no net impact on water quality from the point sources not being considered individually. Level 2 involves multiple model runs in which the NPDES dischargers are added to the model one at a time based on the size of their CBOD load to determine the WLAs necessary to achieve WQS. If necessary, Level 3 involves analyzing the NPDES dischargers outside the Christina Basin (i.e., those discharging to the tidal Delaware River) in order to meet WQS in the tidal Christina River.

The ultimate endpoints of these low-flow TMDLs are the daily average and the minimum DO criteria for the various stream segments in the study area. DO concentrations vary throughout the course of a 24-hour day and tend to follow a general sinusoidal pattern with the lowest point occurring just before sunrise and the highest value occurring in the afternoon. In general, controlling CBOD has a greater impact on the daily average DO than on the diel (24-hour period) DO range. Depending on whether a system is nitrogen or phosphorus limited, the available nitrogen or phosphorus influences the diel DO range due to the impact on algae and periphyton growth kinetics. The model calibration and validation indicated that phosphorus is the limiting nutrient in the freshwater streams in the Christina River Basin (*Hydrodynamic and Water Quality Model of Christina River Basin Final Report, May 31, 2000)*. In Section 9.6 of the Model Report, it is noted that there was an abundance of nitrogen available and that phosphorous is the more limiting of the two nutrients based on data at five locations. The five locations were in West Branch Brandywine Creek, East Branch Brandywine Creek, Brandywine Creek (at Chadds Ford), Christina River and West Branch Red Clay Creek. Time-series plots at each location are found in Figures 9-12 through 9-16 in the Model Report.

The allocation process proceeds by reducing the CBOD, nitrogen, and phosphorus loads from the NPDES point sources in equal percentages until the daily average DO criteria are satisfied. After this is accomplished, if the minimum DO criteria have not been met, then the phosphorus loads will be further controlled until the diel DO range is reduced sufficiently to satisfy the minimum DO criteria.

Since these TMDLs deals with low-flow conditions only, by definition very little nonpoint source load from land-based sources will be entering the system during drought conditions. The nonpoint source flows from peripheral tributaries and groundwater sources are considered to be at baseline (i.e., background) conditions. The baseline concentrations for the various water quality parameters were determined from all data in the STORET database for the period 1988 to 1998. The 10th percentile concentration values were assumed to be indicative of the nonpoint source contributions during the 7Q10 low-flow period. The concentrations were within the range of expected values for watersheds in the eastern United States according to Omernik (1977). The baseline concentrations for total nitrogen and total phosphorus are presented in Table 9.

Table 9. Baseline Concentrations of Nitrogen and Phosphorus for Christina Basin TMDL

Subwatershed	Total Nitrogen (mg/L)		Total Phosphorus (mg/L)	
	Baseline	Omernik (1977) (67% range)	Baseline	Omernik (1977) (67% range)
Main Stem and East Branch Brandywine Creek	1.56	0.33 - 6.64	0.01	0.008 - 0.251
West Branch Brandywine Creek	2.44	0.33 - 6.64	0.03	0.008 - 0.251
Red Clay Creek	2.65	0.33 - 6.64	0.05	0.008 - 0.251
White Clay Creek	2.31	0.33 - 6.64	0.02	0.008 - 0.251
Christina River	1.08	0.33 - 6.64	0.02	0.008 - 0.251

Source: STORET data 1988-1998 and Nonpoint Source Stream Nutrient Level Relationships (Omerrnik, 1977)

Level 1 Allocation Results - Baseline Allocations

The first level of the size-based EMPR allocation involved considering each NPDES discharger individually to determine if WQS for DO were met. Those dischargers not considered individually were set to the baseline conditions in Table 9. This allowed the in-stream flow to remain at 7Q10 levels and created no net impact on water quality from the point sources not being considered individually. If WQS were not met, then CBOD, nitrogen and phosphorus for the individual point source were reduced in 5% increments until standards were achieved. Of the 99 NPDES point sources located in the Christina River Basin, 87 of them are small, with flow rates of 0.25 mgd or less. In order to avoid making 87 individual model runs to determine whether a Level 1 allocation was needed, all the small NPDES discharges were grouped into a single model run. The model results for this run indicated that the WQS for daily average DO and minimum DO were protected at all locations in the Christina River Basin. Thus, if as a group there were no violations of the DO standard for the small dischargers, then individually there would be no violations.

Next, the remaining 12 large NPDES dischargers were analyzed individually. Of these 12, only four indicated violations of the DO standards: (1) PA0026531 (Downingtown) on the East Branch Brandywine Creek, (2) PA0026859 (Coatesville City) on the West Branch Brandywine Creek, (3) PA0024058 (Kennett Square) on West Branch Red Clay Creek, and (4) MD0022641 (Meadowview Utilities) on West Branch Christina River. The Downingtown facility caused violations of the minimum DO standard but not the daily average DO standard. The other three facilities caused violations of both the daily average and minimum DO WQS (see Figures 11 and 12). The Level 1 load reductions necessary to achieve compliance with the WQS for DO are shown in Table 10.

Table 10. Level 1 Baseline Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 1 Allocation Limits			Level 1 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0026531	7.0	10	2.0	2.0	10	2.0	1.6	0%	0%	20%
West Branch Brandywine Creek										
PA0026859	3.85	15	2.0	2.0	10.5	2.0	1.05	30%	0%	48%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	17.5	2.1	1.35	30%	30%	82%
West Branch Christina River										
MD0022641	0.7	22**	6.45*	1.0	22**	2.0	1.0	0%	69%	0%

* no permit limits, values shown are based on monitoring data
** value shown is BOD5; MD permits list BOD5 instead of CBOD5

PA0026531 - Downingtown Area Reg. Auth.
PA0026859 - Coatesville City Authority
PA0024058 - Kennett Square
MD0022641- Meadowview Utilities, Inc.

Level 2 Allocation Results

The second level of the size-based EMPR allocation strategy involved adding the dischargers one at a time based on the size of Level 1 baseline CBOD allocations (kg/day) and performing waste load allocations to those stream segments indicating violations of the DO WQS. The daily average and minimum DO results of the initial Level 2 run are shown in Figures 13 and 14. It is apparent that the DO WQS are not being met in the East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek and West Branch Christina River with the two largest dischargers added to each of these stream reaches. The allocation proceeded by running the water quality model in an iterative fashion by reducing CBOD, NH3-N, and TP in 5% intervals for all NPDES dischargers upstream of the farthest downstream model grid cell indicating a DO violation. Once WQS were achieved at the 5% increment level, the allocations were fine tuned in 1% increments. After the allocations were fine tuned, the next largest discharger was added to the stream reach and the process was repeated until all dischargers were included in the analysis.

No allocations were made to point sources on the main stem Brandywine Creek until the stream segments on the East and West Branches were first in compliance with WQS. The small residence dischargers (0.0005 mgd), groundwater cleanup dischargers, and water filtration plant backwash facilities were not included in the allocation analysis since, as noted before, a model run covering all small dischargers indicated that the WQS for daily average DO and minimum DO were protected at all locations in the Christina River Basin. Furthermore, filtration backwash facilities only discharge as needed and not on a continual basis. The Level 2 allocation results are presented in Table 11 and are shown in Figures 15 and 16. It can be seen that there are no violations of the daily average DO or minimum DO criteria at any point inside the Christina River Basin. Thus, a Level 3 allocation will not be necessary for the tidal Christina River.

Table 11. Level 2 Allocations

NPDES Facility	Flow (mgd)	Existing Permit Limits			Level 2 Allocation Limits			Level 1 and 2 Percent Reduction		
		CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5 (mg/L)	NH3-N (mg/L)	TP (mg/L)	CBOD5	NH3-N	TP
East Branch Brandywine Creek										
PA0043982	0.4	25	2.0*	2.0	14.38	2.0	1.15	42%	0%	42%
PA0012815	3.0	34	6.0	1.0	19.55	3.45	0.58	42%	42%	42%
PA0026531	7.0	10	2.0	2.0	5.75	1.15	0.91	42%	42%	54%
West Branch Brandywine Creek										
PA0026859**	3.85	15	2.0	2.0	10.5	2.0	1.05	30%	0%	48%
West Branch Red Clay Creek										
PA0024058	1.1	25	3.0	7.5*	16.62	1.99	1.28	34%	34%	83%
PA0057720-001	0.05	10	2.0	2.0*	9.50	1.90	1.90	5%	5%	5%
West Branch Christina River										
MD0022641**	0.7	22***	6.45*	1.0	22***	2.0	1.0	0%	69%	0%

* no permit limits, values shown are based on typical characteristics or monitoring data
**allocation did not change from Level 1 allocation
***value shown is BOD5; MD permits list BOD5 instead of CBOD5

PA0026531 - Downingtown Area Reg. Auth.
PA0024058 - Kennett Square
PA0043982 - Broad Run Sew. Co.
PA0057720-001 - Sunny Dell Foods, Inc.
PA0026859 - Coatesville City Authority
MD0022641- Meadowview Utilities, Inc.
PA0012815 - Sonoco Products

In Appendix A of this document, data plots are presented which show DO WQS, impacts of NPDES permitted loads and the TMDL model results for the proposed TMDL waste load reductions for each major Christina River Basin segment.

Performance data for the year 2000 for the three largest facilities (Downingtown, Coatesville and Sonoco Products) indicate that these facilities are already achieving generally consistent performance near or below the proposed level 2 reductions. The main exception is the phosphorous discharges at Downingtown and Coatesville. Additional information on performance of major Christina River Basin dischargers is available in the Model Report (Table 7-3 - 1997 data used in model calibration) and recent performance information can be obtained from the appropriate state agencies.

Waste Load Allocations (WLAs)

Federal regulations at 40 CFR 130.7 require TMDLs to include individual WLAs for each point source. Tables 12-27 outline the individual WLAs for those dischargers in the Christina River Basin. Of the 122 NPDES facilities considered, only those 12 dischargers considered during the Level 1 and Level 2 EMPR analysis require reductions to their NPDES permit limits for those pollutants listed above.

Load Allocations

According to Federal regulation at 40 CFR 130.2(g), load allocations are best estimates of the nonpoint or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.

Nonpoint source loads within the Christina River Basin model are based on monitoring data from STORET, USGS water quality data, baseflow samples taken in 1997, and interstate monitoring data collection efforts. The loads represent expected low-flow contributions from subwatersheds according to the delineation of the 39 subwatersheds in the HSPF model currently being developed by USGS. This will allow the HSPF model to be directly linked to the EFDC model to investigate seasonality and address high flow situations. Those data sets were used to develop characteristic loads of parameters of concern (carbon, nitrogen, phosphorus, DO and algae) for each of the 39 subwatershed as delineated by the HSPF model. Load allocations were based on actual site-specific data and are broken down by subwatershed in Tables 12-27 below.

Allocations Scenarios

EPA realizes that its determination of the total loads below for carbonaceous biochemical oxygen demand (5-day), ammonia nitrogen, total nitrogen, total phosphorus and DO to the point sources and nonpoint sources is one allocation scenario. As implementation of the established TMDLs proceed, the states and DRBC may find that other combinations of point and nonpoint source allocations are more feasible and/or cost effective. However, any subsequent changes in the TMDLs must conform to gross WLAs and load allocations for each segment and must ensure that the biological, chemical, and physical integrity of the waterbody is preserved.

Federal regulations at 40 CFR 122.44(d)(1)(vii)(B) require that, for an NPDES permit for an individual point source, the effluent limitations must be consistent with the assumptions and requirements of any available WLA for the discharger prepared by the state and approved by EPA. EPA has authority to object to the issuance of an NPDES permit that is inconsistent with WLAs established for that point source. To ensure consistency with these TMDLs, as NPDES permits are issued for the point sources that discharge the pollutants of concern to the Christina Basin, any deviation from the

WLAs described herein for the particular point source must be documented in the permit Fact Sheet and made available for public review along with the proposed draft permit and the Notice of Tentative Decision. The documentation should: (1) demonstrate that the loading change is consistent with the goals of these TMDLs and will implement the applicable WQS, (2) demonstrate that the changes embrace the assumptions and methodology of these TMDLs, and (3) describe that portion of the total allowable loading determined in the TMDL report that remains for other point sources (and future growth where included in the original TMDL) not yet issued a permit under the TMDL.

It is also expected that the states will provide this Fact Sheet, for review and comment, to each point source included in the TMDL analysis as well as any local and state agency with jurisdiction over land uses for which load allocation changes may be impacted. EPA believes that this gives flexibility to the state agencies to address point source trading within the NPDES permitting process. However, should these trading activities result in changes to the total loading by basin or subwatershed segment, then EPA would expect that revisions would be necessary and the states or DRBC would need to follow the formal TMDL review and approval process.

In addition, EPA regulations and program guidance provide for effluent trading. Federal regulations at 40 CFR 130.2 (i) state: "If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then WLAs may be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs." The states may trade between point sources and nonpoint sources identified in these TMDLs as long as three general conditions are met: (1) the total allowable load to the waterbody is not exceeded, (2) the trading of loads from one source to another continues to properly implement the applicable WQS and embraces the assumptions and methodology of these TMDLs, and (3) the trading results in enforceable controls for each source. Final control plans and loads should be identified in a publicly available planning document, such as the state's water quality management plan (see 40 CFR 130.6 and 130.7(d)(2)). These final plans must be consistent with the goals of the approved TMDLs. While the nature and considerations of the low flow TMDL make trading between point and nonpoint sources unavailable, EPA expects that this option will be available when the high-flow TMDLs are developed.

3) The TMDLs consider the impacts of background pollutant contributions.

Background pollutant contributions are the result of non-anthropogenic sources such as from stream erosion, wild animal wastes, leaf fall, and other natural or background processes[19]. During low-flow, summer conditions baseflow contributions to the river are considered most influential and are representative of background contributions.

In terms of the low flow TMDL analysis, EPA used monitoring data from STORET, USGS water-quality data from monitoring stations, baseflow samples collected in 1997 (Senior 1999), and data from a field study conducted by Dr. John Davis of Widener University. Furthermore, atmospheric loads from both dry and wet deposition are considered. EPA believes that use of actual instream monitoring data and atmospheric data will effectively account for background pollutant contributions.

As previously mentioned, the Christina River Basin drains to the Delaware River Estuary, which is affected by tidal influences. Furthermore, the Christina River, Brandywine Creek and White Clay Creek also experience similar tidal effects. The tides are the movement of water above and below a datum plane, usually sea level, which causes tidal currents[20]. Tides are the result of the gravitational forces of the sun and moon on the earth.

Of particular importance when considering tidal influences is the net estuarine flow which is the flow that flushes material out of the estuary over some period of time. Estuaries typically have complicated flow patterns from tidal motion impacts resulting in vertical stratification where freshwater inflow rides over saline ocean water. In essence then, any discharge of pollutants to the Delaware River above and below the confluence of the Christina River and the Delaware River, within a certain distance, could potentially impact water quality within the tidally influenced portions of the Christina River Basin.

It is important to recognize that these pollutant loads are discharged outside the Christina River Basin. However, increased pollutant loads from these sources could negatively impact water quality within the tidally influenced segments of the Christina River Basin causing violations of WQS. Therefore, EPA included the point source loads for those dischargers on the Delaware River in Table 28 above and EPA considers them as background conditions for the estuary. While sensitivity analyses to determine the exact nature and magnitude of impacts to water quality in the tidal portions of the Christina River Basin from increased or decreased pollutant loads from the Delaware Estuary have not been performed, any changes to pollutant loads from these sources should strive to be consistent with the existing pollutant loads in the estuary.

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[19] Supra, footnote 4. (EPA 1999 Protocol for Developing Nutrient TMDLs) Pg 5-5.

[20] Supra, footnote 5. (Thomann, Mueller) Section 3.

4) The TMDLs consider critical environmental conditions.

Federal regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for streamflow, loading and water quality parameters. The intent of this requirement is to ensure that the water quality of all waterbodies of the Christina River Basin are protected during times when it most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of WQS and will help in identifying the actions that may have to be undertaken to meet WQS.[21] Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that result in attaining and maintaining the water quality criterion and have an acceptably low frequency of occurrence. In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. For example, stream analysis often uses a low flow (7Q10) design condition as critical because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum. Additionally, the *Technical Support Document for Water Quality-based Toxics Control (EPA 505-2-90-001)* recommends the 1Q10 flow (minimum 1-day flow expected to occur every 10 years) or 7Q10 as the critical design periods when performing water quality modeling analysis. Historically, these so-called "design" flows were selected for the purposes of WLA analyses that focused on instream DO concentrations and protection of aquatic life[22]. Pennsylvania, Delaware and Maryland specify 7Q10 as the design or critical conditions for the application of water quality criteria in their WQS.

The Christina River Basin TMDLs adequately addresses critical conditions for flow through the use of 7Q10 flows during the model period from August 1 to August 31. The 7Q10 values are based on data from 17 USGS stream gages in the Christina River Basin. Table 29 below presents flow statistics from USGS gages in the basin.

[21] EPA Memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Water Management Division Directors, August 9, 1999.

[22] Supra, footnote 17. (EPA 1994 Water Quality Standards Handbook) Section 5.2.

Table 29. Summary of Flow Statistics from USGS Gages in the Christina River Basin

USGS Gage ID	Drainage Area (mi^2)	Years of Record	Average Flow	Harmonic Mean	7Q10 Flow	1Q10 Flow	7Q1 Flow	1Q1 Flow
01478000	20.5	1944-94	28.21	8.31	1.53	0.54	3.79	1.83
01478500	66.7	1952-79	85.91	47.10	11.00	10.15	24.05	22.38
01478650		1994		38.66				
01479000	89.1	1932-94	114.65	62.19	15.60	14.04	31.23	28.45
01479820		1989-96		24.69				
01480000	47.0	1944-94	63.39	36.51	10.25	8.91	18.38	16.37
01480015		1990-94		41.08				
01480300	18.7	1961-96	26.25	12.83	3.40	3.01	6.62	6.19
01480500	45.8	1944-96	66.33	34.64	8.24	7.34	15.41	14.21
01480617	55.0	1970-96	91.31	52.79	19.02	15.54	24.84	21.63
01480650	6.2	1967-68	6.00	3.51				
01480665	33.4	1967-68	36.36	23.45				
01480700	60.6	1966-96	93.46	50.53	13.86	12.17	21.84	19.87
01480800	81.6	1959-68	86.63	44.81	12.56	11.86	20.57	18.81
01480870	89.9	1972-96	153.43	87.17	28.44	23.62	37.66	34.63
01481000	287.0	1912-96	395.13	234.13	70.63	65.04	117.01	107.14
01481500	314.0	1947-94	477.01	266.73	78.13	71.96	123.45	113.32

Source: USGS

In terms of pollutant loading, the critical conditions for point source loads occur during times when maximum flow and concentrations are being discharged. The maximum flows and loads are based on the NPDES permits for each facility. These conditions for point sources are used in the critical condition analysis and allocation scenarios.

Nonpoint source loads were based on monitoring data from STORET as well as data collected by USGS, baseflow samples collected in 1997 and data collected by DEP and DNREC and are representative of background contributions as well as expected land-based, nonpoint sources during low-flow conditions. During these conditions, land-based nonpoint sources are expected to contribute very little pollutant loadings to the waterbody. Furthermore, the ability of the waterbody to assimilate pollutant loads during these low-flow conditions is at a minimum. Consideration of nonpoint source loads would simply remove assimilative capacity and cause further reductions to point sources in order to achieve WQS. As can be seen from Table 8, in most watersheds point sources are the dominant contributors of pollutant loadings in low-flow conditions. The data sets were used to develop characteristic loads of parameters of concern (carbon, nitrogen, phosphorus, DO and algae) for each of the 39 subwatersheds as delineated by the HSPF model.

Use of these loads in the model provides the ability to integrate past pollutant loading events. It is recognized that delayed impacts on DO levels from wet-weather events during critical summertime periods may occur. However, Thomann and Mueller observed that "for some rivers and estuaries, the deposition of solids proceeds only during the low flow summer and fall months when velocities are low. High spring flows the following year may scour the bottom clean and reduce the problem until velocities decrease again. Intermediate cases are common where high flows may scour only a portion of the deposit, oxidize a portion, and then redeposit the material in another location."[23] It is likely that the use of site-specific data to characterize nonpoint source loads during critical conditions would consider those sporadic summertime loading events. In addition, both wet and dry deposition of atmospheric loads are included in the EFDC model.

The water quality parameters of concern are DO and nutrients throughout the system. However, as previously discussed, DO can be affected by BOD, SOD, algae and reaeration. These parameters, in addition to nitrogen and phosphorus, are addressed within the linkage analysis to ensure that the pollutant allocation scenario will ensure that WQS are met and maintained throughout the system.

5) The TMDLs consider seasonal environmental variations.

Addressing seasonal variation, similar to critical conditions, is necessary to ensure that WQS are met during all seasons of the year. Seasonal variations involve changes in streamflow as a result of hydrologic and climatological patterns. In the continental United States, seasonal high flow normally occurs during the colder period of winter and in early spring from snowmelt and spring rain, while seasonal low flow typically occurs during the warmer summer and early fall drought periods[24]. Other seasonal variations include reduced assimilative capacity from changes in flow and temperature as well as sensitive periods for aquatic biota. Seasonal fluctuations in both point and nonpoint source loads must also be considered.

In terms of the point source loads, the values used in the model are representative of those loads expected during the summer season based on DMRs, NPDES permit limits or characteristic concentrations. Likewise, the use of data from STORET, USGS and baseflow sampling to characterize expected nonpoint source loads during the summer will effectively consider seasonality.

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[23] Supra, footnote 5. (Thomann, Mueller) Section 6.3.4.

[24] Supra, footnote 8. (EPA 1997 Technical Guidance for Developing TMDLs) Section 2.3.3.

EPA expects that seasonal variations will continue to be addressed through the development of the HSPF model in conjunction with the TMDLs for high-flow conditions. Once this model is linked with EFDC, this will provide EPA with a powerful tool to investigate seasonality, critical conditions and alternate allocation strategies on a larger temporal and spatial scale. However, use of the EFDC model to represent critical low-flow summer conditions prior to development of the HSPF model in no way downgrades the scientific validity or defensibility of the current TMDL analysis and allocation scenario. Regardless, use of the fully integrated and linked model would still require consideration of critical conditions and seasonality. It is reasonable to expect that the allocation scenario from this integrated analysis would reflect the same critical condition and seasonality components in the current low-low analysis and result in similar pollutant loading allocations.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty or lack of knowledge. MOSs may be implicit, built into the modeling process, or explicit, taken as a percentage of the WLA, load allocation, or TMDL.

In consideration of the sheer quality and quantity of data, and the development of the HSPF watershed loading model which will be linked to this EFDC model, EPA is utilizing an implicit MOS through the use of conservative assumptions within the model application. An example of a conservative assumption used in this model is the discharge of point sources located on tributaries directly into the model without consideration of attenuation in the tributary water. The effect is conservative in terms of the main stem river segment since modeling directly to the main stem will not consider potential attenuation between the point of discharge into the tributary and confluence with the downstream main stem segment. This could potentially affect the pollutant allocation scenario. The exact nature of the effect is not known and could be positive or negative. The reverse, however, is not conservative when considering the tributary since negative water quality impacts could be occurring. The ability to model these water quality effects is extremely limited due to lack of resources, time and data and use of this conservative assumption is valid.

Additional factors in the MOS for the TMDLs for the Christina River Basin include:

- All point sources were set to their maximum permitted loads for the TMDL allocations.
- Streamflows were set to critical 7Q10 conditions for the TMDL allocations.
- No shading of the stream due to vegetation canopy was incorporated into the model, therefore, full sunlight conditions reach the stream during daylight hours resulting in maximum photosynthetic activity. Also, no cloud cover was incorporated into the model TMDL allocation runs resulting in maximum solar radiation reaching the stream.

- Stream water temperatures were set to critical high values based on historical data at USGS monitoring stations.

- Finally, all of the above items occur simultaneously resulting in very conservative conditions for the TMDL allocations.

It should be pointed out that this modeling effort relies on data which could be easily characterized as extensive and high-quality. The number of USGS stations and water quality stations, period of record, multiple sources of data, site-specific studies, and comprehensive review and analysis of the model application and techniques all contribute to the confidence EPA has in this TMDL analysis.

7) The TMDLs have been subject to public participation.

Public participation is a requirement of the TMDL process and is vital to its success. At a minimum, the public must be allowed at least 30 days to review and comment prior to establishing a TMDL. In addition, EPA must provide a summary of all public comments and the response to those comments to indicate how the comments were considered in the final decision.

For several years, the CBWQMC and the CBWQMC Policy Committee have served as valuable forums to discuss Christina River Basin issues including the low-flow TMDL study. During the past two years as the work on the TMDLs has accelerated and reached completion, updates on the status of the TMDLs have been presented at the following meetings. These meetings, while not explicitly inviting the general public, were nonetheless open to the public:

- CBWQMC Meetings: March 12, 1999, April 22, 1999, August 5, 1999, January 28, 2000, March 30, 2000 and October 12, 2000.

- CBWQMC Policy Committee Meetings: October 29, 1999, May 31, 2000, July 7, 2000, November 3, 2000 and November 30, 2000.

In addition to the above meetings, a Public Outreach Task Force of the CBWQMC, led by Bob Struble of the Brandywine Valley/Red Clay Creek Valley Association, has held regular meetings to discuss Christina River Basin issues, including these TMDLs.

A special meeting of Public Outreach Task Force was held on May 24, 2000. Invitations to the major dischargers in the Christina River Basin were distributed for this meeting and representatives from Northwestern Chester Municipal Authority, Downingtown Area Regional Authority, City of Coatesville Authority, Bethlehem Steel Corporation, West Chester/Taylor Run STP and the Cecil County, MD Department of Public Works were in attendance. Also attending were representatives of Delaware and Maryland and engineers representing facilities in the Christina River Basin. During this meeting, the draft modeling results and allocations from the Christina River Basin TMDL model were presented and discussed. The model results and allocations were also discussed at a May 31, 2000 Public Outreach Task Force meeting and the May 31, 2000 Policy Committee meeting as well. Additional discharger representatives from Sonoco, Inc. and Kennett Square were present at the May 31 meetings. During the December 1, 2000 Public Outreach Task Force meeting, EPA provided a status report on the Christina River Basin TMDLs.

The CBWQMC has published annual reports summarizing activities and ongoing work for the past several years. The Phase III report, which included a summary of the work completed to date on the Christina River Basin TMDLs and planned future work, was published on August 5, 1999.

A public meeting sponsored by the Delaware Nature Society on the Christina River Basin was held at the Ashland Nature Center in Delaware on June 17, 1999. A presentation on the Christina River Basin TMDLs was included on the agenda.

The proposed Christina River Basin low-flow TMDLs were the subject of two public information meetings on July 18-19, 2000 in West Chester, PA and Wilmington, DE. As result of information received at these meetings, changes were made to the proposed TMDLs and revised draft TMDLs were presented at two formal public hearings on August 29-30, 2000 in West Chester, PA and Wilmington, DE. The public meetings and hearings were the subject of a July 12, 2000 EPA press release and the meetings were advertized in the Wilmington News-Journal, West Chester Local News and the Chester County Papers consortium. EPA held the comment period for the draft TMDLs open through October 15, 2000. As a result of comments received at the public hearings, and during the public comment period, additional changes were made to the Christina River Basin low-flow TMDLs. Comments submitted at the public hearings and prior to the close of the public comment period were reviewed and a public comment responsiveness summary prepared which accompanies this final TMDL Decision Rationale document.

As noted before, EPA Region III established a web site for the Christina River Basin TMDLs to serve as an information clearinghouse for these TMDls. Information related to the proposed TMDLS was posted on this site and included meeting announcements, summaries of presentations and draft TMDL documents. The web site also provided a means for the public to submit comments on the proposed TMDLs

8) There is reasonable assurance that the TMDLs can be met.

Reasonable assurance indicates a high degree of confidence that each WLA and load allocation in a TMDL will be implemented. EPA expects the states to implement these TMDLs by ensuring that NPDES permit limits are consistent with the WLAs described herein. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of an NPDES permit that is inconsistent with WLAs established for that point source. Additionally, according to 40 CFR 130.7(d)(2), approved TMDL loadings shall be incorporated into the states' current water quality management plans. These plans are used to direct implementation and draw upon the water quality assessments to identify priority point and nonpoint water quality problems, consider alternative solutions and recommend control measures. This provides further assurance that the pollutant allocations of the TMDLs will be implemented.

In terms of the nonpoint sources, the load allocations are representative of expected pollutant loads during critical conditions from baseflow, atmospheric, and traditional land-based sources. These loadings are not expected to vary significantly. Therefore, reductions from the current load allocations are unnecessary to meet WQS under low-flow conditions. Reasonable assurance that the current load allocations will be met is based on the extensive data set used to characterize the current nonpoint source pollutant loadings. In addition, the feasibility of control measures necessary to reduce current nonpoint source pollutant loadings under the baseflow critical conditions defined for these low-flow TMDLs is highly questionable. Control measures for nonpoint source flows under higher flow regimes have been demonstrated to be feasible and the control of nonpoint source flows will be evaluated in the high-flow TMDL.

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